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Wind Driven Single Switched Transformerless Step-down Converter

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Abstract

This paper presents a wind driven high step-down transformer less single-stage single-switch ac/dc converter. The topology integrates a buck-type power-factor correction (PFC) cell with a buck–boost dc/dc cell and part of the input power is coupled to the output directly after the first power processing. With this direct power transfer feature and sharing capacitor voltages, the converter is able to achieve efficient power conversion, high power factor, low voltage stress on intermediate bus and low output voltage without a high step-down transformer. The absence of transformer reduces the component counts and cost of the converter. Unlike most of the boost-type PFC cell, the main switch of the proposed converter only handles the peak inductor current of dc/dc cell rather than the superposition of both inductor currents. Detailed analysis and design procedures of the proposed circuit are given and verified by experimental results.

Keywords: — Direct power transfer (DPT), integrated buck–buck–boost converter (IBuBuBo), power-factor correction (PFC), single-stage (SS), transformerles.

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I. INTRODUCTION

AC/DC is one of the most common power conversions in power electronics, DC loads should be fed with a stable and a tight regulated voltage. At the same time, the AC/DC converter should comply with low-frequency harmonic regulation.

AC/DC converters are mainly single stage and two stage converters. Single stage converters reduce cost, size, complexity and it has simple control mechanism. Present single stage ac/dc converters are consisting of mainly a boost power factor correction cell. But using the boost PFC cannot attain a voltage below the input line voltage and it have several disadvantages, it cannot reduce the input surge current

.To decrease the voltage below input line voltage a high step down transformer is needed, by the presence of transformer leakage inductance is increased and it causes lower efficiency in conversion .So we have to introduce a new topology to overcome these disadvantages. To decrease the line voltage below the input voltage we combined a buck power factor correction cell and buck-boost dc/dc converter. This topology eliminates the transformer, thus we can achieve high conversion efficiency without any leakage inductance. By the use of buck power factor correction cell, this circuit reduces the inrush of surge current at input. Proposed topology is known as integrated buck- buck boost converter (IBuBuBo converter).It can be limit bus voltage below 400v. Positive output voltage is possible by using this converter. Another advantage of this converter is it uses one ideal switch, this helps to make simple circuitry and control mechanism. Power factor correction reduces the harmonic distortion.

II. PROPOSED SYSTEM

The closed loop control of an integrated buck buck-boost converter has been proposed in this paper. By doing open loop simulation we can see that although we are getting a dc voltage in the output, ripple content in the output waveform is more. So as a modification a closed loop simulation is done using a PI controller. Closed loop simulation is done in order to regulate the output voltage. Output voltage is held constant regardless of input voltage or some other variations. The output voltage wave form contains very less amount of ripple contents. The simulink models of closed loop simulations using PI controller and its output voltage and current waveforms are presented below.

Differential heating of the earth's surface by the sun causes the Movement of large air masses on the surface of the earth,i.e., the wind. Wind energy conversion systems convert the kinetic energy of the wind into electricity or other forms of energy. Wind power generation has experienced a tremendous growth in the past decade, and has been recognized as an environmentally friendly and economically competitive means of electric power generation

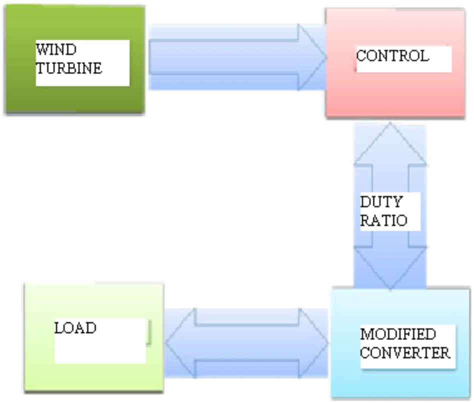

Fig.1. Block Diagram

III. BASIC COMPONENTS

A. Wind turbine: There are mainly two types of wind turbines: Horizontal axis and Vertical axis. The Horizontal axis wind turbines (HAWT) and Vertical axis wind turbines (VAWT) are classified and differentiated by axis of rotation of rotor shafts.

1. Horizontal Axis Wind Turbines: Horizontal Axis Wind Turbines also known as HAWT type turbines has a horizontal rotor shaft and electrical generator both is located at the top of the tower.

2. Vertical Axis Wind Turbines: Vertical axis wind turbines also known as VAWT type turbines has a vertical rotor a generator and a gear box which are placed at the bottom of the turbine and a uniquely shaped rotor blade that are designed to harvest the power of the wind no matter which direction it is flowing.

B. PI controller: PI controller will eliminate forced oscillations and steady state error resulting in operation of on-off controller and P controller respectively. However, introducing integral mode has a negative effect on speed of the response and overall stability of the system.

Thus, PI controller will not increase the speed of response. It can be expected since PI controller does not have means to predict what will happen with the error in near future. This problem can be solved by introducing derivative mode which has ability to predict what will happen with the error in near future and thus to decrease a reaction time of the controller. PI controllers are very often used in industry, especially when speed of the response is not an issue.

C. Step Down Converter: In this paper, an intergrated buck– buck–boost (IBuBuBo) converter with low output voltage is proposed. The converter utilizes a buck converter as a PFC cell. It is able to reduce the bus voltage below the line input voltage effectively. In addition, by sharing voltages between the intermediate bus and output capacitors, further reduction of the bus voltage can be achieved. Therefore, a transformer is not needed to obtain the low output voltage. The converter is shown in figure 2.

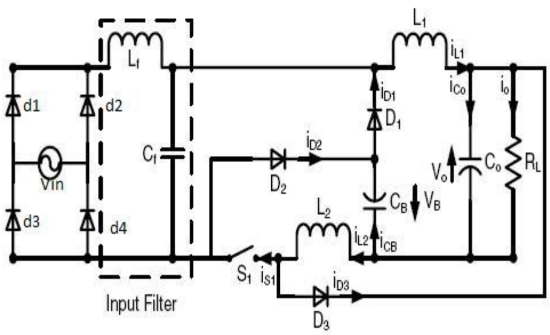

Fig.2. Step down Converter

IV. BASIC OPERATING PRINCIPLE

The proposed IBuBuBo converter, which consists of the merging of a buck PFC cell (L1 , S1 , D1 , Co , and CB) and a buck–boost dc/dc cell (L2 , S1 , D2 , D3 , Co , and CB) is illustrated in Figure 2. Although L2 is on the return path of the buck PFC cell, but it does not contribute to the cell electrically. Thus, L2 is not considered as in the PFC cell. Moreover, both cells are operated in discontinuous conduction mode (DCM) so there are no currents in both inductors L1 and L2 at the beginning of each switching cycle t0.

Due to the characteristic of buck PFC cell, there are two operating modes in the circuit .Mode A and Mode B. To simplify the circuit analysis, some assumptions are made as follows:

1. All components are ideal;

2. Line input source is pure sinusoidal, i.e. vin (θ) =Vpksin(θ), where Vpk and θ are denoted as its peak voltage and phase angle, respectively;

3. Both capacitors CB and Co are sufficiently large such that they can be treated as constant DC voltage sources without any ripples;

4. The switching frequency fs is much higher than the line frequency such that the rectified line input voltage |vin

(θ)| is constant within a switching period.

Mode A (vin (θ)≤VB + Vo): When the input voltage vin (θ) is smaller than the sum of intermediate bus voltage VB , and output voltage Vo , the buck PFC cell becomes inactive and does not shape the line current around zero-crossing line voltage, owing to the reverse biased of the bridge rectifier. Only the buck–boost dc/dc cell sustains all the output power to the load. Therefore, two dead-angle zones are present in a half-line period and no input current is drawn as shown in Figure 3.Figure 4.2 shows input voltage and current waveformfor a half-line period

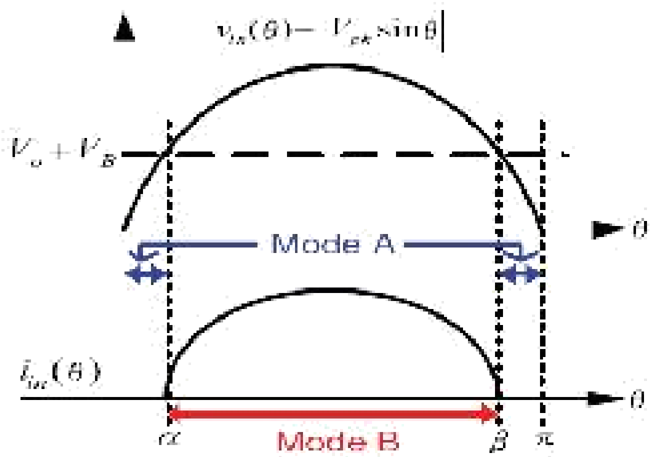

Fig.3. Input voltage and current wave forms

The circuit operation within a switching period can be divided into three stages corresponding sequence is Fig. 4(a),(b), and(f).

1. Stage 1 (period d1Ts in Fig. 5(a)) [see Fig. 4(a)]: When switch S1 is turned ON, inductor L2 is charged linearly by the bus voltage VB while diode D2 is conducting. Output capacitor Co delivers power to the load.

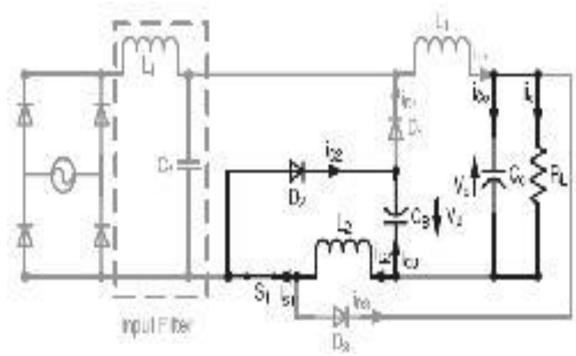

Fig.4(a).Circuit operation of stage 1 of ModeA

2) Stage 2 (period d2Ts in Fig. 5(a)) [see Fig. 4(b)]: When switch S1 is switched OFF, diode D3 becomes forward

biased and energy stored in L2 is released to Co and the load. This process is illustrated clearly in the figure 5.

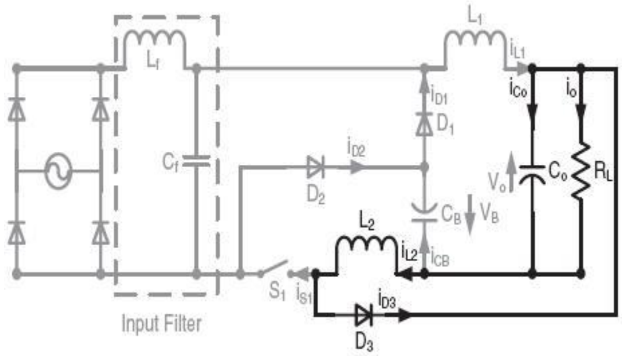

Fig.4(b). Circuit operation of stage 2 of Mode A

3) Stage 3 (period d3Ts - d4Ts in Fig. 5(a)) [see Fig4.3 (f)]: The inductor current iL2 is totally discharged and only Co sustains the load current.

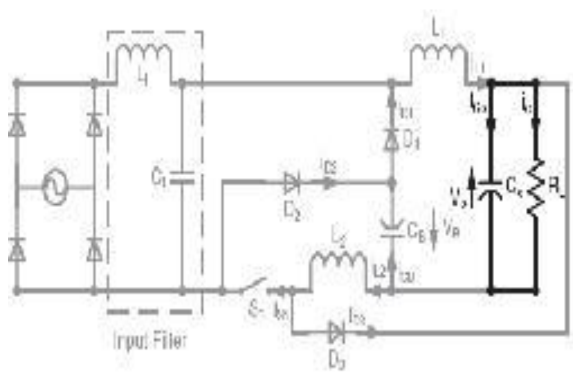

Fig.4(f).Circuit operation of stage 3 of Mode A and stage 4 of Mode B

Mode B (vin (θ) > VB + Vo): This mode occurs when the input voltage is greater than the sum of the bus voltage and output voltage. The circuit operation over a switching period can be divided into four stages and the corresponding sequence is Fig. 4(c), (d), (e), and (f).

1. Stage 1 (period d1Ts in Fig. 5(b)) [see Fig. 4(c)]: When switch S1 is turned ON, both inductors L1 and L2 are charged linearly by the input voltage minus the sum of the bus voltage and output voltage (vin (θ) − VB − Vo), while diode D2 is conducting.

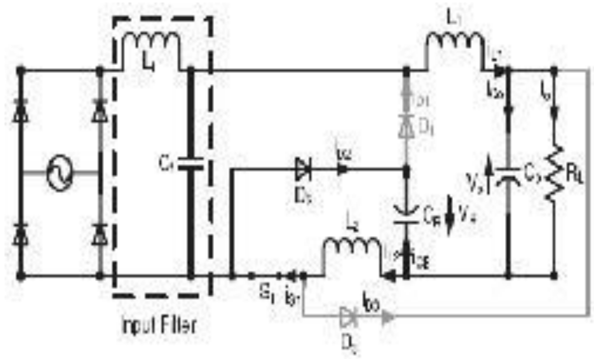

Fig.4(c). Circuit operation of stage 1 of Mode B

2) Stage 2 (period d2Ts in Fig. 5(b)) [see Fig. 4(d)]: When switch S1 is switched OFF, inductor current iL1 decreases linearly to charge CB and Co through diode D1 as well as transferring part of the input power to the load directly. Meanwhile, the energy stored in L2 is released to Co and the current is supplied to the load through diode D3. This stageends once inductor L2 is fully discharged.Figure 8 shows this working mode of the converter. It helps us to examine it easily

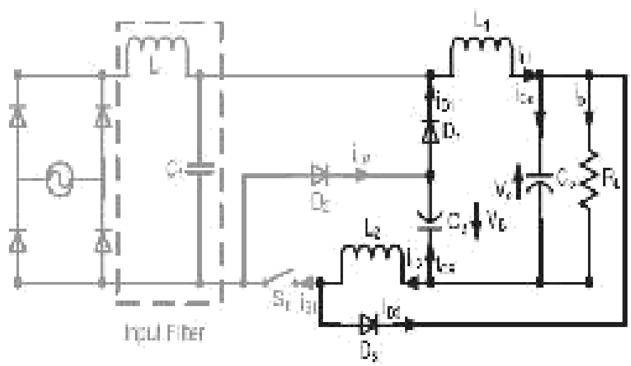

Fig.4(d). Circuit operation of stage 2 of mode B

3) Stage 3 (period d3Ts in Fig. 5(b)) [see Fig. 4.3(e)]: Inductor L1 continues to deliver current to Co and the load until its current reaches zero.

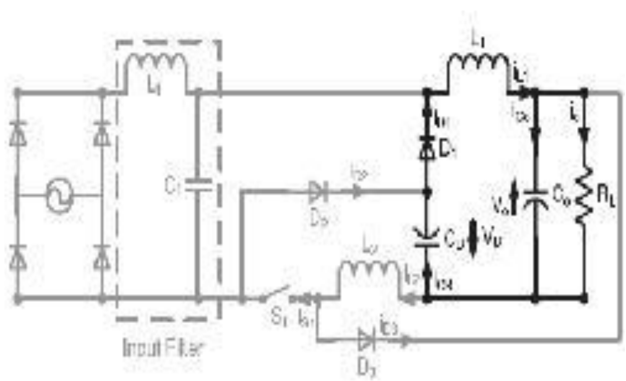

Fig.4(e) Circuit operation of stage 3 of Mode B

4) Stage 4 (period d4Ts in Fig. 5(b)) [see Fig. 4. (f)]: Only Co delivers all the output power.

Following figures shows the key waveforms of the circuit at different switching periods.

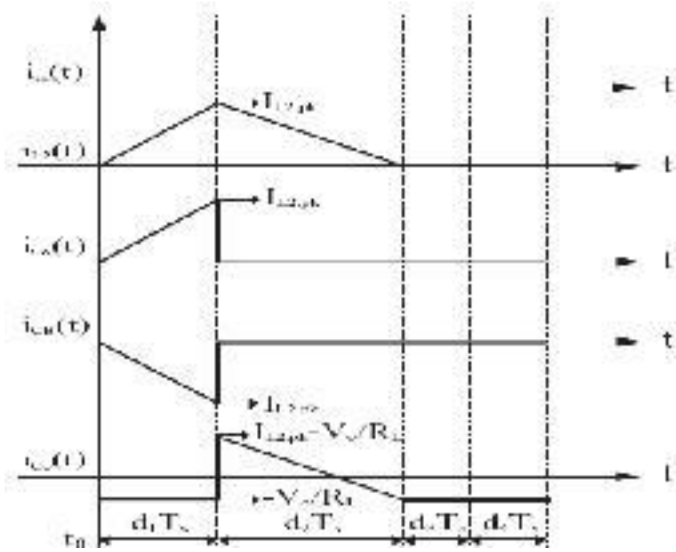

Fig 5(a) Key waveforms of the circuit for Mode A

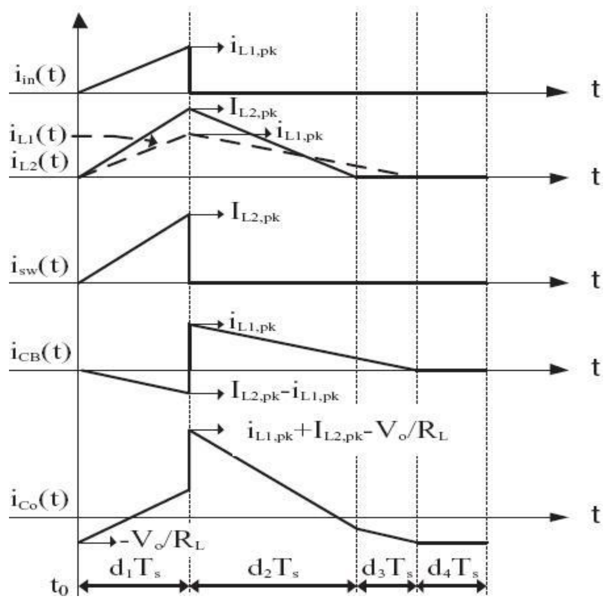

Fig 5(b) Key waveforms of the circuit for Mode B

A. Operating principle of Wind Turbine

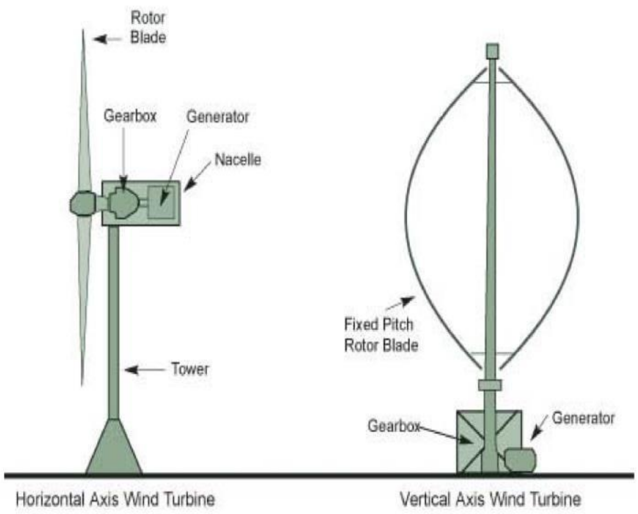

Fig.6.Wind Turbine

Figure 6 shows HAWT and VAWT type turbines.

- The rotor is an elegant aerofoil shaped blades which take the wind and aerodynamically converts its kinetic energy into mechanical energy.

- The gear box alters the rotational velocity of the shaft to suit the generator.

- The generator is a device that produces electricity when mechanical work is given to the system.

- The protection system is like a safety feature that makes sure that turbine will not be working under dangerous condition. This includes a brake system triggered by a signal of higher wind speeds to stop the rotor from movement under excessive and guts.

- The tower is the main shaft that connects the rotor to the foundation. It also raises the rotor in the air where we can find stronger winds. With Horizontal axis wind turbines, the tower houses stairs to allow for maintenance and inspection.

- The foundation or the base supports the entire wind turbine and make sure that it is fixed onto the ground or the roof for small household wind turbines. This is usually consists of a concrete assembly around the tower to maintain its structural integrity.

V. SIMULATION AND RESULTS

A. Simulink model for existing open loop system

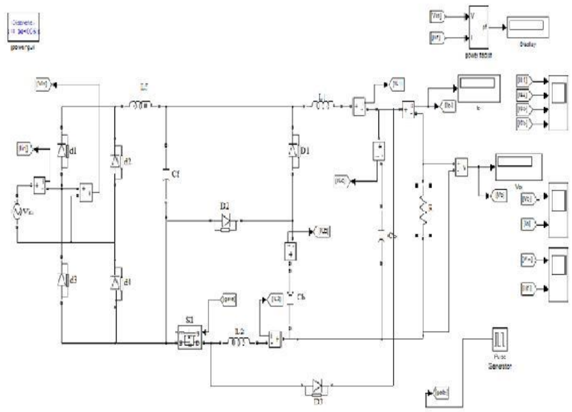

Fig.7. simulink model for existing open loop system

The main disadvantage of this system was output voltage was not pure DC. This problem was solved by using a PI controller in the system ths making it a closed loop system. Figure 8 shows simulink model for closed loop system.

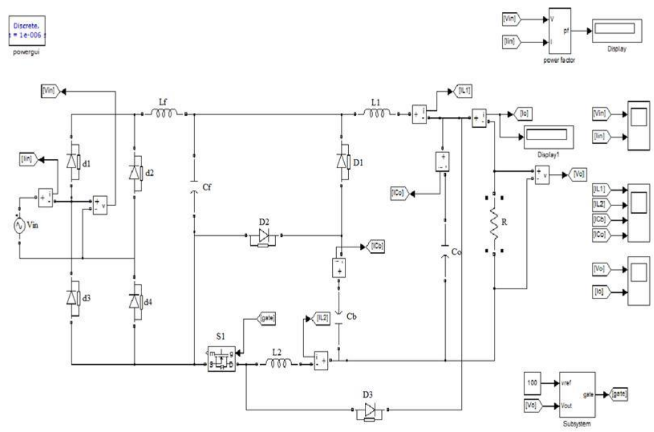

Fig.8. Simulink model for existing closed loop system

B. Advantage of closed loop system

- Since we are using closed loop control we get more regulated output.

- Considerable improvement in power factor..

In closed loop system different values of output voltage can be obtained according to the reference

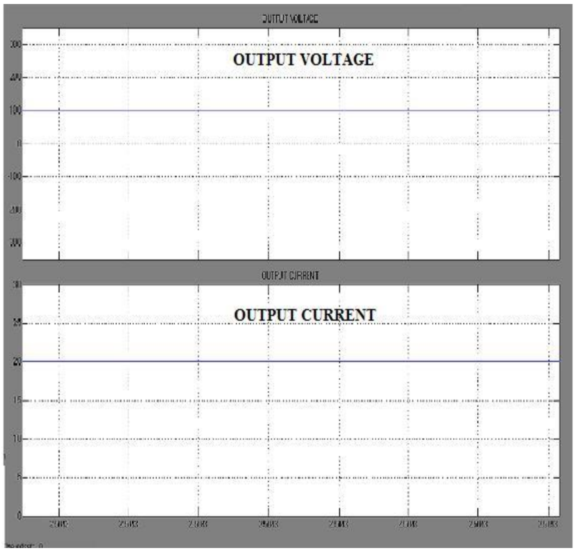

Fig.9.Output voltage and current waveform of closed loop system

C.Simulink model for proposed wind driven system

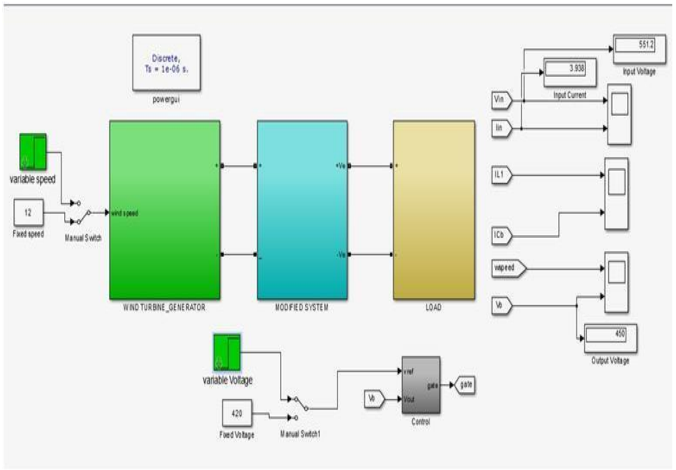

Fig.10. Simulink model for proposed wind driven system

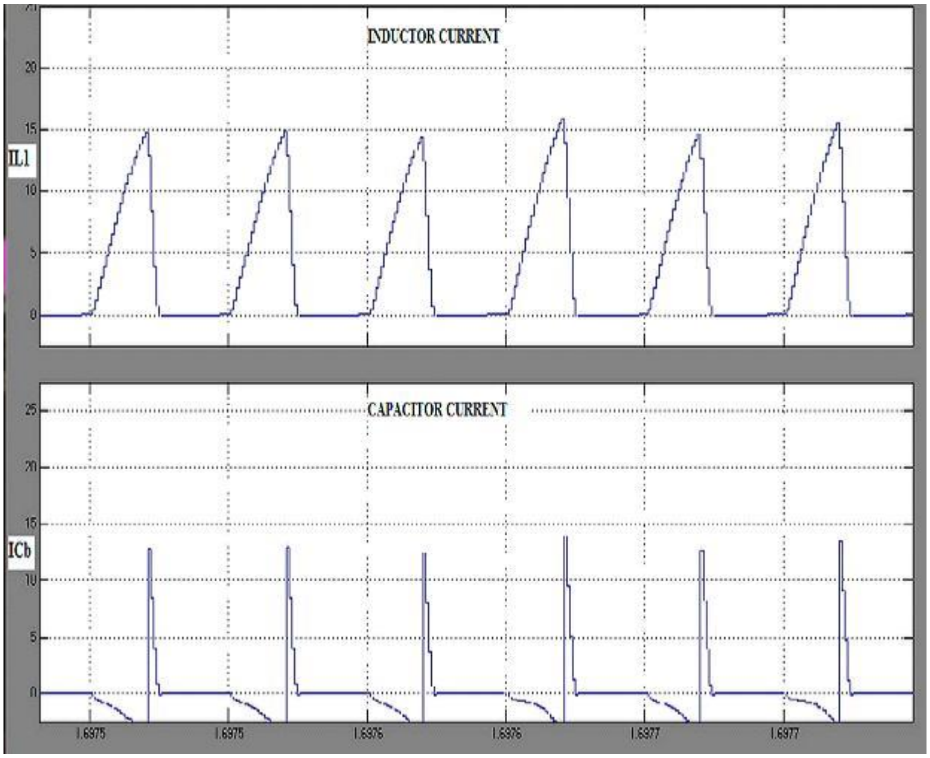

Fig.11.Indutor and capacitor current waveforms of proposed system

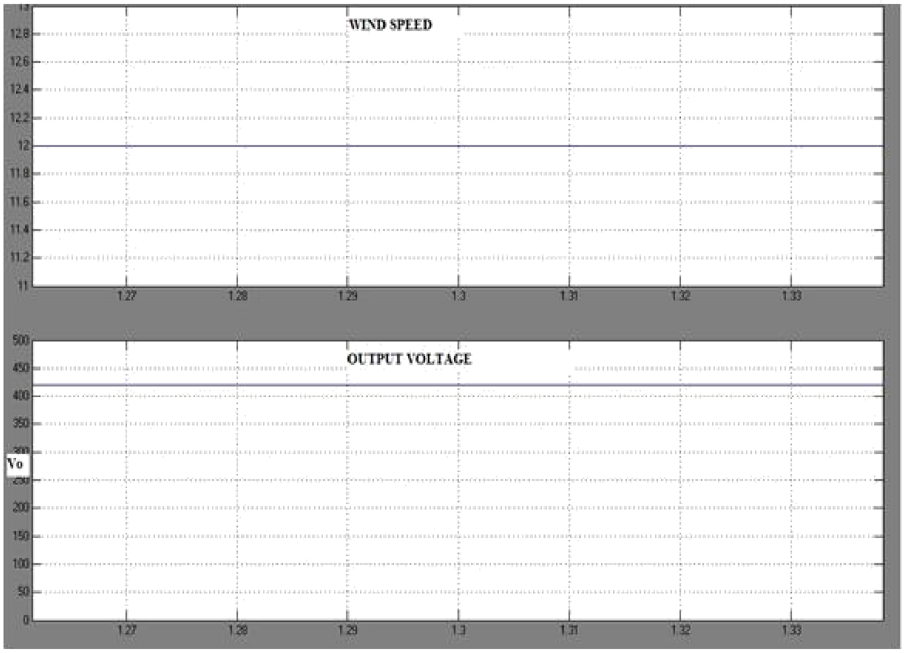

Fig.12.Wind speed and Output voltage waveform of proposed system

TABLE I. INPUT AND OUTPUT VALUES

INPUT VOLTAGE	551.20V
OUTPUT VOLTAGE	450V

REFERENCES

[1] Alonso. J. M, Dalla Costa. M. A, and Ordiz C.,[2008] “Integrated buck-flyback converter as a high-power-factor off-line power supply,” IEEE Trans. Ind.Electron., vol. 55, no. 3, pp. 1090–1100

[2] Antonio. L, B. Andrs, S. Marina, Vicente.S. , and

Emilio.O,[2007] “New power factor correction AC-DC converter with reduced storage capacitor voltage,”IEEE Trans. Ind. Electron., vol. 54, no. 1, pp. 384–397.

[3] Heng-Yi Li and Hung-Chi Chen, Member, IEEE.”Dynamic Modeling and Controller Design for a Single-Stage Single-Switch Parallel Boost-Flyback– Flyback Converter “..

[4] Ismail. E. H, Sabzali A. J, and Al-Saffar M. A,[2008] “Buck–boost-type unity power factor rectifier with extended voltage conversion ratio,” IEEE Trans. Ind. Electron., vol. 55, no. 3, pp. 1123–1132Y. IEEE Transl. J. Magn. Japan, vol. 2, pp. 740–741, August 1987].

[5] M. Young, The Technical Writer's Handbook. Mill Valley, CA: University Science, 1989.